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AGRICULTURAL BIOTECHNOLOGY RESEARCH CAPACITY IN FOUR DEVELOPING COUNTRIES

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In 1998, ISNAR conducted a biotechnology research indicator survey of four national agricultural research systems—in Mexico, Kenya, Indonesia, and Zimbabwe—to provide an overview of their agricultural biotechnology research capacities. The findings reveal several factors that limit the development of such a capacity. Advanced biotechnology techniques are being used in only a few public sector research organizations, and most organizations are still in the first stages of developing their capacity. Most research activities were focused on crops, with a limited focus on livestock. Although expenditures for research grew annually in each country, the number of researchers grew much faster, and expenditures remained small when compared to total research expenditures. The public sector accounted for most of total expenditures (92% on average), while private sector participation remained limited. Although agricultural biotechnology has received some government attention, a comprehensive strategy for the development of biotechnology was still lacking in the sampled countries. Some of the policy recommendations for overcoming these limitations include increasing investment in agricultural biotechnology research, promoting private sector involvement, fostering collaboration between the public and private sectors, and designing a comprehensive strategy for the development of biotechnology.

Introduction

A good indicator of efforts to strengthen or create agricultural biotechnology capacity is the level of funding available for investment. Data regarding the size, structure, and content of public research are also needed to improve policy decisions, clarify the roles of the public and private sectors, and support public sector implementation of biotechnology research. Unfortunately, there is a lack of structured data on resources for agricultural biotechnology in developing countries. An exhaustive review of the literature reveals few studies that colected and analyzed such data at the national level. Such studies were conducted in Brazil, Argentina, Venezuela, and Costa Rica, but the data on investment and human resources for public and private organizations involved in agricultural biotechnology activities were gathered and analyzed for only one year (1989).

The paucity of research in this area prompted ISNAR to conduct a survey to gather statistical, institutional, and policy information

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on the development of agricultural biotechnology research in Mexico, Kenya, Indonesia, and Zimbabwe. These four countries were selected to permit comparison on the basis of population size and development of agricultural biotechnology. Within the sample, Mexico, with one of the largest populations, was the most advanced in biotechnology; Indonesia, with the largest population, had an intermediate level of biotechnology; and Kenya and Zimbabwe, with much smaller populations, both developed an intermediate-low level of biotechnology.

The survey gathered information in three parts. The first part described the relevant biotechnology programs or institutions and how they developed in each country. The second part focused on information related to the physical, human, and financial resources available for agricultural biotechnology. The final part identified the research projects in agricultural biotechnology being conducted by the sampled institutions. The periods of analysis were from 1985 to 1997 in Mexico, from 1989 to 1996 in Kenya, from 1989 to 1997 in Indonesia, and from 1989 to 1998 in Zimbabwe.

The survey covered the most relevant public and private organizations involved in agricultural biotechnology research. Out of the 34 organizations surveyed, 13 were public research institutes, 11 were public universities, 6 were private non-commercial organizations, and 4 were private commercial entities. This sample represents around 70% to 80% of the total expenditures on agricultural biotechnology research in each country. The expenditures are presented below in real international dollars and converted by the purchasing power parity (PPP) index to allow a comparison with other countries' expenditure levels.

This paper provides a brief summary and analysis of ISNAR's findings. The first section recounts the historical development of each country's biotechnology infrastructure. In the second section, the data pertaining to various indicators of biotechnology capacity are reviewed. Finally, the survey's findings are summarized and several policy recommendations are outlined.

Institutional and policy development

Each country followed a different path in developing its biotechnology capacity. This is largely a reflection of the influence of donors, and of differences in implementation, i.e. when a strategy was actually in place. The development of each country's biotechnology infrastructure is summarized below.

Mexico established its first tissue culture laboratory in 1970. After a review of the national biotechnology situation in the early 1980s, several national biotechology research units were established—the Biotechnology Institute of the Autonomous National University of Mexico, the Center for Research and Advanced Studies, Irapuato Unit (CINVESTAV-I), and the Scientific Research Center of Yucatan (CICY). Since the 1980s, these three research centers have employed advanced biotechnology techniques, and because of this, Mexico is one of the most advanced in biotechnology among the developing countries today.

Several developments followed: in 1989 the Biosafety Committee was established; in 1991, industrial property legislation was approved; Plant Breeders' Rights (PBR) were also legislated. Mexico thus became the first developing country to explicitly patent biotechnological inventions. In the early 1990s, the government launched a national program to modernize science and technology. Its aim was to achieve international standards of scientific excellence. At the same time, Mexico obtained a World Bank loan for building scientific capacity and infrastructure. However, no priority areas were identified in this project, and biotechnology was not explicitly mentioned. The same holds true for the 1995-2000 national development plan.

Despite having no explicit biotechnology policy or strategy in place, Mexico has made considerable developments in biotechnology in recent years. The country is now close to generating the first transgenic product to be released by a national organization in Latin America (through CINVESTAV-I, in joint collaboration with Monsanto). This resulted in part from the above developments, as well as from Mexico's membership in the North American Free Trade Agreement, and from competition in the North American market.

Indonesia started a few years later than Mexico, formulating the National Program Development of Biotechnology in 1983 as the national strategy and policy for biotechnology. In order to implement this strategy, the Government of Indonesia established two centers in 1985: the Inter-University Center for agricultural biotechnology at the Bogor Agriculture Institute, in order to train university faculty in biotechnology; and the Research and Development Center for Biotechnology (RDCB) at the Indonesian Institute of Sciences (LIPI), with a mandate to enhance national capacity in biotechnology. In 1989, the Biotechnology Division of the Central Research Institute for Food Crops (CRIFC) of the Agency for Agricultural Research and Development (AARD) was established. In 1990, the Indonesian government selected CRIFC and RDCB to be exemplary “centers of excellence” for agricultural biotechnology. These two organizations utilize advanced biotechnology techniques, and are the leaders of agricultural biotechnology research in Indonesia.

In 1995, in accordance with the national development plan, the Research Institute for Food Crops Biotechnology (RIFCB) was created after merging the Biotechnology Division of CRIFC and the Bogor Research Institute for Food Crops. RIFCB is now the main biotechnology arm at AARD.

With regards to legislation, the Biosafety Regulations and the Biosafety Commission were established in 1997. In 1989, Indonesia approved a patent law, which was revised to extend protection to biotechnology products. However, Plant Breeders’ Rights are still lacking.

Due to expectations that biotechnology will play a significant role in achieving and maintaining sustainable agricultural production, the government of Indonesia has, since the mid-1980s, placed a priority on biotechnology for the development of agriculture. Even though the government gave priority status to biotechnology, implementing their plans required a significant amount of resources. The government therefore launched a special grant program in 1992 to provide funds for research in biotechnology and other sciences. Unfortunately, this strategy has been seriously affected by the Asian financial crisis of 1997, and biotechnology research activities in this country have since experienced a drastic decline in funding.

Zimbabwe and Kenya were found to be at very similar levels of biotechnology development. The Kenya Agricultural Research Institute (KARI) started its biotechnology activities in 1982, and is leading agricultural biotechnology research in Kenya. In Zimbabwe, the Biotechnology Research Institute (BRI) at the Scientific and Industrial Research and Development Centre (SIRDC) was established in 1992, and was the nation’s leader in biotechnology.

Biotechnology in both countries gained momentum in 1992 with the Special Program on Biotechnology, which was established with the support of the government of the Netherlands. This Special Program brought the first elements of biotechnology planning to both countries through a priority-setting exercise including farmers, researchers, extensionists, and policymakers. One result of this exercise was the creation of both the Kenya Agricultural Biotechnology Platform and the Zimbabwe Biotechnology Advisory Committee in 1996. The Netherlands supports agricultural biotechnology through these two entities, which advise the government and the Dutch-supported special programs on developing agricultural biotechnology in both countries.

Kenya appointed the Biosafety Committee in 1996, implemented the Industrial Property Act in 1993, and approved the Plant Varieties Act in 1994. Meanwhile, in Zimbabwe, biosafety regulations were established only in 1998, and the National Biosafety Committee only in 1999. Zimbabwe has had Plant Breeders’ Rights and an industrial patent law since 1970s, but these have yet to accommodate biotechnology products. With the introduction of Dutch support, and with both the Kenyan and Zimbabwean governments’ recognition of biotechnology’s role in the development of the agricultural sector, agricultural biotechnology research is expected to develop and expand.

Even though the creation of biosafety committees and the revision of property rights legislation both favor private sector participation in agricultural biotechnology research, such participation remains limited in all four countries. A few firms, such as Empresa La Moderna in Mexico (which did not participate in the ISNAR survey), are engaged in advanced biotechnology research, but most private companies specialize in lower risk procedures and higher value crops, such as tissue culture on fruits and ornamentals.

Research indicators

The survey data pertaining to the structure, organization, human resources, expenditures, and financing of biotechnology research are analyzed below.

Structure and organization

Only eight (about 20%) of the research organizations surveyed were considered to be specialized in biotechnology, because their core activity is biotechnology research (see table 1). Four of these organizations started their research activities only recently. The remaining organizations were considered to be non-specialized, or merely using biotechnology as a tool to support other research activities. They utilized biotechnology research to complement their primary activities, integrating biotechnology into the process of generating research results.

The sectoral composition of agricultural biotechnolgy research, based on research expenditures, is presented in table 2. This research is carried out mainly by public-sector organizations, which accounted for almost 92% of all research expenditures during the period of analysis. The participation of the private sector amounted to only 8% on average, yet, with the exception of Indonesia, this sector had a high annual growth rate. Moreover, the universities showed the only negative growth—a significant decline in research expenditures. This can be attributed to economic recession, as well as the cyclical nature of donor funding. For example, the departments of biochemistry and crops sciences of the University of Nairobi and the University of Zimbabwe received a substantial lump-sum donation in the early 1990s that distorted their research expenditure figures during the period of analysis. In the case of Mexico, the government funds most universities, so the 1995 recession could be a factor affecting the decline in public universities' research expenditures.

Table 1. Biotechnology Research Organizations, 1997

Country	Number of Organizations	
	Core Activity	Support Activity
Kenya	1	5
Mexico	3	11
Indonesia	3	5
Zimbabwe	1	5
Total	8	26

Public research institutes constituted not only the largest source of financing but also showed the highest annual growth rate (Mexico and Kenya, 9%, Indonesia, 30%, and Zimbabwe, 70%). Financial resources are concentrated in a small number of public research institutes: in Kenya, KARI accounts for 70% of total expenditures in 1996; in Zimbabwe, BRI took 80% in 1998; in Indonesia, 70% was divided among three research organizations in 1997; and in Mexico, 3 organizations received 55% in 1997. This is in sharp contrast to the situation in most of the developed countries, where the public sector generally holds a much smaller share of resources. For example, in 1992 in the United States, 70% of financial resources in agricultural biotechnology research came from the private commercial sector.

Most of the researchers involved in biotechnology focused on crops research (almost 75% in Kenya, 100% in Mexico, 90% in Indonesia, and 80% in Zimbabwe), while the few remaining worked in livestock research programs. This lesser focus on livestock did not correspond its actual contribution to agricultural production value, which was 50% in Kenya in 1996, 45% in Mexico in 1997, 30% in Indonesia in 1997, and 35% in Zimbabwe in 1998.

Table 2. Distribution of Total Research Expenditures by Sector (%)

Sector	Mexico		Kenya		Indonesia		Zimbabwe	
	1985	1997	1989	1996	1989	1997	1989	1998
Public Research Institute	50	60	47	72	66	85	1	81
Public University	50	28	49	24	14	11	98	3
Private Non-Commercial	0	4	4	4	0	1	0	16
Private Commercial	0	8	0	0	20	3	0	0
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Personnel

Within the periods of analysis, the total number of researchers more than doubled, with the numbers holding Ph.D. degrees increasing by at least three times (*see table 3*). Growth in the number of researchers can probably be explained by several developments, including a significant increase in the number of post-graduate programs in biotechnology, the establishment of specialized research organizations that require more scientists trained in biotechnology, and the creation of special grant programs to encourage scientists to become involved in biotechnology research.

As with financial resources, the researchers surveyed were concentrated in a few public research organizations. Around 45% of the Kenyan researchers were located in KARI, 60% of Mexican researchers were in only four organizations, 60% of Indonesians were in only three, and 70% of Zimbabweans were in only three as well.

Genetic engineering and tissue culture have a recommended ratio of two technical support personnel to one researcher. However, in the four countries surveyed, there were on average two researchers for every technician. Most of the research organizations showed a low ratio of technical support to researchers, a factor that can seriously affect the development of research outputs. Only three private commercial entities (2 in Mexico, 1 in Indonesia) had a higher ratio than recommended—an average of five technicians per researcher.

Table 3. Agricultural Biotechnology Research Personnel

Researchers[a]	Mexico		Kenya		Indonesia		Zimbabwe	
	1985	**1997**	**1989**	**1996**	**1989**	**1997**	**1989**	**1998**
PhD	14	127	14	41	50	102	5	27
MS	12	49	12	15	28	93	5	31
BSc	25	62	6	9	47	154	9	23
Total	**51**	**238**	**31**	**64**	**125**	**349**	**19**	**81**
Researcher to Technical Support Ratio	3.1	2.1	2.0	1.4	1.3	1.4	1.1	2.1

(a) On leave researchers were not included.

Expenditures

The number of researchers in agricultural biotechnology research in Kenya, Mexico, and Zimbabwe grew much quicker than research expenditures (see table 4). This led to an annual decline of some 7% in expenditures per researcher. Only two private commercial entities in Mexico showed positive growth and a higher level of expenditures per researcher than the public sector.

Indonesia was the only country to show a significant annual growth rate in expenditures per researcher during the period of analysis. However, expenditures per researcher declined in 1997 due to the Asian financial crisis. In that year, all research organizations in Indonesia experienced negative growth, and the most significant decline was in the private commercial sector (*see table 2*).

It is worth noting that expenditures per researcher in the larger countries, Mexico and Indonesia, were higher than those of the smaller countries, Kenya and Zimbabwe. This suggests that Mexican and Indonesian researchers have more resources for generating biotechnology research results, and therefore a higher probability of doing so.

The research intensity ratio—i.e., the ratio of agricultural biotechnology research expenditures to the agricultural gross domestic product (AgGDP)—has grown annually. However, the percentage of the agricultural gross domestic product that actually went to biotechnology research remained quite minimal—at 0.12% in Zimbabwe, 0.04% in Mexico and Kenya, and 0.014% in Indonesia. On the other hand, these expenditures accounted for a larger proportion of total agricultural research expenditures on average, at around 2.3% for Kenya, 6.5% for Mexico, 7% for Indonesia, and 5% for Zimbabwe.

Table 4. Expenditures on Agricultural Biotechnology Research

Expenditures	Mexico 1985	Mexico 1997	Mexico Annual Growth	Kenya 1989	Kenya 1996	Kenya Annual Growth	Indonesia[a] 1989	Indonesia[a] 1997	Indonesia[a] Annual Growth	Zimbabwe 1989	Zimbabwe 1998	Zimbabwe Annual Growth
In millions of 1985 PPP dollars	9.7	20.4	8.5%	2.5	3.0	2.6%	2.4	18.7	29.3%	1.8	3.5	7.5%
In nominal US$ millions	4.3	11.5	6.3%	1.0	1.2	2.5%	0.7	6.0	30.8%	1.0	1.4	3.8%
Per researcher, in thousands of 1985 PPP dollars	187.5	85.1	-6.4%	77.2	45.5	-7.2%	19.1	53.6	13.7%	92	43	-8.0%
As a % of Agricultural GDP	0.026	0.052	5.9%	0.046	0.048	0.6%	0.003	0.018	25.1%	0.12	0.23	7.5%
% of Agricultural Research Total	3.1	9.6	9.8%	3.3	2.8	-2.3%	1.7	9.6	24.1%	4.6	10.0	9.0%

(a) Total agricultural research expenditures include only Agency for Agricultural Research and Development (AARD) figures.

There are no standards for how much of a country's agricultural research budget should be allocated to biotechnology. For the sake of comparison, the CGIAR spent about 8% of its budget on biotechnolgy research in 1997, while the United States allocated 13% of its agricultural research expenditures (including private and public expenditures) to biotechnology in 1992. Throughout the periods of analysis, biotechnology investments in the selected countries came to only a fraction of United States biotechnology expenditures: Mexico and Zimbabwe invested only around 9% and 12% of the U.S. amount, respectively, and Kenya and Indonesia only 4%. This exemplifies the great disparity between developed and developing countries in terms of the amount of resources that can be committed to biotechnology research. Research leaders and decision-makers should consider this disparity when planning the development of biotechnology in their own countries.

Financing

Table 5 presents the sources that funded agricultural biotechnology research activities during the periods of analysis. Public research institutes in Kenya and Zimbabwe were funded mainly by donor contributions, and this funding was concentrated in each country's primary research institutions. KARI in Kenya received almost 85% of total donor support in 1996, and BRI in Zimbabwe received almost 90% in 1998. The donor share was considerable in the same countries, accounting for an average of 67% and 50%, respectively, of total expenditures. Without any effort to acquire funding from local sources, these levels of funding will be compromised in the medium term.

Table 5. Sources of Research Funding (%)

Source	Kenya (1996)	Mexico (1997)	Indonesia (1997)	Zimbabwe (1998)
Government	28	60	93	34
Donors	67	24	2	50
Product sales	3	12	4	16
Contracts	0	4	1	0
Levies	2	0	0	0
Total	**100**	**100**	**100**	**100**

In Mexico and Indonesia, government contributed about 60% and 93%, respectively, of total expenditures on agricultural biotechnology. Donor share was 25% in Mexico, but almost negligible in Indonesia (2%). Some public research institutes and universities supported their biotechnology research activities through non-traditional sources of funding, such as sales of products and services, and contractual arrangements. Although these non-traditional sources are minimal, they increased markedly during the periods of analysis. In the private sector, contracts or levies fund biotechnology activities carried out by non-com- mercial organizations, while commercial organ- izations are financed by the sales of their products.

Funding from non-traditional sources remains limited, indicating a minor relationship between the private/commercial sector and the public sector's research institutes and universities. An earlier study argued that, in Mexico, this relationship remains limited because the private sector can import technology more cheaply, the government neglects the use of science to foster economic development, the regulatory framework impedes the introduction of biotechnology products by foreign and local companies, research scientists tend not to be business-oriented, and more funding mechanisms are needed to draw the two sides closer together.

Techniques

The techniques being used by researchers are a good indicator of a country's biotechnology capacity. Two techniques were selected to determine the degree of technical sophistication achieved by the sampled research organizations. Genetic engineering was used as an indicator of advanced research capacity in biotechnology, while tissue culture was used as an indicator of a more limited, less- advanced capacity.

As shown in table 6, about half of all researchers in Mexico and Indonesia utilized advanced techniques, while the other half used less-sophisticated techniques. In Kenya and Zimbabwe, around 70% of researchers used less-advanced techniques, while 30% used more advanced techniques. It became clear that advanced biotechnology techniques were regularly used by only a few public research organizations. Judging from the predominant use of tissue culture, most organizations in the sample were still in the early stages of developing their biotechnology capacity.

There was a sectoral divide in terms of the techniques used in biotechnology research. This sectoral divide is important because it reflects the divergent interests of public and private organizations, a factor that must be noted by those interested in promoting partnership between these sectors. In all four countries, private-sector organizations used mainly less-advanced techniques such as tissue culture. Such techniques are less costly, less risky, and have more immediate market payoffs. Public sector organizations made more use of advanced techniques such as genetic engineering, which are more expensive and have uncertain payoffs. However, a significant proportion of public researchers still used less-advanced techniques. This is explained by the continuum of techniques employed in the public sector (where advanced techniques are complemented by less-sophisticated techniques), and by the application of biotechnology to "orphan" commodities, as well as to problems facing marginal farmers.

Table 6. Use of Advanced and Less-Advanced Techniques by Public and Private Sector (% based on the number of researchers)

Technique	Kenya (1996)		Mexico (1997)		Indonesia (1997)		Zimbabwe (1998)	
	Public	Private	Public	Private	Public	Private	Public	Private
Tissue Culture	76	100	68	90	40	90	66	67
Genetic Engineering	24	0	32	10	60	10	34	33
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Findings and Policy Recommendations

The survey produced a number of findings regarding the resources for and the growth of agricultural biotechnology in the sampled countries:

- Most of the organizations sampled appeared to be in the first stages of developing their biotechnology research capacity.

- Although expenditures for agricultural biotechnology research grew annually, the proportion of total agricultural research expenditures allocated to biotechnology was small—less than half that of the U.S.A.

- The number of researchers grew much faster than expenditures. This led to a significant decline in operating expenditures per researcher, a marker of potential problems in terms of sustainability and performance.

- The funding and implementation of biotechnology research is highly dependent on the public sector. The participation of the private sector remains limited at this time.

- Donor contributions constituted the largest source of funding for agricultural biotechnology research in Kenya and Zimbabwe. Donor dependency raises concerns regarding the maintenance and expansion of agricultural biotechnology.

- Most agricultural biotechnology research is focused on crops, with limited resources devoted to livestock.

- The private sector focuses on the market-oriented, low-technology end of biotechnology, and on horticultural crops such as ornamentals and fruits. Such choices indicate a focus on high-value crops that bring a faster payback.

- Governments have paid attention to agricultural biotechnology by establishing biotechnology research centers, creating post-graduate programs, and formulating regulatory frameworks for biosafety and intellectual property rights. Though these developments still require a comprehensive strategy, such efforts form a good basis for future developments in biotechnology.

The above findings lead to the following policy recommendations:

- For the countries in question, a development strategy is crucial for fostering biotechnology. Strategic decision-making must incorporte a clear understanding of the costs of biotechnology, its potential to meet national goals, and its potential impact on beneficiaries. Tools for planning and priority setting are needed to help policymakers make informed trade-offs between commodities and research objectives.

- If developing countries want to make agricultural biotechnology a priority, they need to devote more national and institutional resources to funding research and development.

- To achieve sustainability and promote a user focus in biotechnology programs, developing countries need to develop their own internal funding sources.

- To encourage investment and participation by the private sector, the appropriate policies and incentive mechanisms need to be developed. Research in both sectors should be consciously designed to complement rather than compete with each other.

- The policy framework should promote the safe use of biotechnology while encouraging private sector investment and fostering collaboration with the global agricultural research system.

About the Author...

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About ISNAR: The International Service for National Agricultural Research (ISNAR) assists developing countries in making lasting improvements in the performance of their agricultural research systems and organizations. ISNAR promotes appropriate agricultural research policies, sustainable research institutions, and improved research management. ISNAR's services to national research are ultimately intended to benefit producers and consumers in developing countries and to safeguard the natural environment for future generations. A nonprofit autonomous institute, ISNAR was established in 1979 by the Consultative Group on International Agricultural Research (CGIAR). It began operating at its headquarters in The Hague, the Netherlands, on September 1, 1980.

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